The Internet -of -Things:
Review and Research Directions

by

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ABSTRACT

This paper presents a review of the Internet-of-Things (IoT) through four conceptualizations: IoT as liquification and density of information of resources; IoT as digital materiality; IoT as assemblage or service system; and IoT as modules, transactions, and service. From the conceptualizations, we provide a definition of IoT and present its implications and impact on future research in Marketing that interfaces with information systems, design and innovation, data science and cybersecurity, as well as organizational studies and economics. By integrating the implications of IoT with extant literature, we then propose a set of priorities for future research in this area.

Highlights

- Consumer experiences with physical products will be highly visible in an era of IoT
- Physical products are evolving into connected and dynamically reconfigurable service platforms that are socio-cyber-physical
- Information is leaking out and liquifying everywhere and data is ubiquitous
- Consumers personal data allow for personalization of the offering but could result in consumer vulnerabilities
- Shifting boundaries due to information flows in an era of IoT will transform markets and exchanges

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The Internet-of-Things: Review and Research Directions

1. Introduction

Digitization is the conversion of analog information in any form such as text, images, sound or physical attributes to a digital format so that the information can be processed, stored, and transmitted through digital circuits, devices, and networks. In simple, pragmatic terms, digitizing information makes it easier to store, access, and share and process (Tilson, Lyytinen, & Sorensen, 2010; Yoo, Lyytinen, Boland, Berente, Gaskin, Schutz, & Srinivasan, 2010). As the world moves towards an era of Internet-of-Things, this paper argues that a technical process of converting previously static and unmovable information into a dynamic, transportable resource is creating disruption at a Schumpeterian level that is only just beginning. As a simple example, the cup on your desk holds information about its content, volume, color, and location. In an analog world, that information is only known to you as only you are able to see it. In a digital world, all information about that cup can potentially be 'seen' by anyone else. The 'leak' or 'liquification' of such information resources can create engagement and transactions not merely about the product function but also the state, action, and description of the product itself, together with the consumer interacting with it. We argue that such a technological ability that could render every physical object into a potential digital artefact will trigger limitless possibilities, both negative and positive, and could result in fundamental transformation of institutions and other socio-technical structures.

Wireless sensor technologies now allow objects to provide information about their environment, context, and location (e.g. Alemdar & Ersoy, 2010; Ruiz-Garcia, Lunadei, Barreiro, & Robla, 2009); 'smart' technologies are touted as being able to allow everyday things to 'think and interact'; e-textiles or smart textiles are fabrics that enable digital components and electronics to be embedded in them (e.g., Stoppa & Chiolerio, 2014). Even old things could be potentially connected. Surfaces could be coated with conductive paint (e.g., Leong & Chung, 2006); electronic polymers now allow for smart glass as the surface for mirrors (MacDiarmid, 2001; Carpi & De Rossi, 2005); plastic electronics enable circuits to be produced at relatively low cost by printing electronic materials onto any surface, whether rigid or flexible (Kaltenbrunner, Sekitani, Reeder, Yokota, Kuribara, Tokuhara, Drack, Schwödiauer, Graz, Bauer-Gogonea, & Bauer, 2013).

With nanotechnology and energy-scavenging technologies packing more processing power into less space, the potential to connect everything old and new for innovation and economic growth has sent the digital world into a creative tizzy. The term 'Internet-of-Things' (IoT) coined by Kevin Ashton, a technologist and pioneer in the Auto-ID world, has started to gain traction, and industry is beginning to wake up to the possibility of every object being part of the Internet, whatever the business proposition might be. The Internet and the physical world are about to experience an epic collision.

The objective of this paper is to first, review and present four conceptualizations of IoT. These conceptualisations are developed from the following theoretical constructs:

liquification and density of information resources (Normann, 2001); digital materiality (Yoo, Boland Jr, Lyytinen, & Majchrzak, 2012); assemblage (Hoffman and Novak, 2015) and service systems (Ng, 2010) and modularity and transaction network (Baldwin, 2008). From the conceptualizations, we then discuss the implications of an era of IoT and its impact on practices and research in Marketing through 12 research priorities. To be clear, by referring to Marketing, we mean Marketing as defined by the activity, the set of institutions, and the processes for "creating, communicating, delivering, and exchanging offerings that have value for customers, clients, partners, and society at large" (AMA definition, Keefe, 2008). Our paper presents the conceptualizations and implications of IoT and draw the connections back to the principles of Marketing and the research conducted as we have known them for more than 50 years, arguing the impact an era of IoT would cause. In proposing the research priorities, we also integrate with literature from information systems, design and innovation, data science, cybersecurity, as well as organizational studies and strategy. By doing so, we hope to create a step change in expanding the knowledge base of Marketing and persuade researchers to actively engage in interdisciplinary IoT research.

2. Conceptualizations of the Internet-of-Things

The term 'Internet-of-Things (IoT)' was first introduced by Kevin Ashton to describe how IoT can be created by "adding radio-frequency identification and other sensors to everyday objects" (Ashton, 2009). Over time, the term has evolved into one that describes the IoT as a network of entities that are connected through any form of sensor, enabling these entities, which we term as *Internet-connected constituents*, to be located, identified, and even operated upon.

In the next section, we review four useful conceptualizations of IoT characteristics from various literature across the disciplines of strategy, operations management/manufacturing, systems theory, and information systems.

2.1 Internet-of-Things as liquification and density of information resources

One characteristic of the IoT is closely related to the notion of density of information resources. Density refers to "the best combination of resources [that] is mobilized for a particular situation — e.g. for a customer at a given time in a given place — independent of location, to create the optimal value/cost result" (Normann, 2001; Michel, Vargo, & Lusch, 2008). The density of information resources is crucial for achieving resource density. Previously, disparate information sets could be attained at different times and put together through organizational or consumption processes. The process of liquification and transportation of the information resource across space and time that is contextually relevant could enhance density of information resources (Normann, 2001; Michel et al, 2008). For Normann (2001), liquification refers to the separation of information from the physical objects, allowing the information to be easily moved about and re-manifested in many different ways (Michel et al, 2008). Liquification entails the transformation of a physical object's underlying information, description, or definition into information resources (Lusch & Nambisan, 2015). Liquification of the physical is able to generate a combination of disparate information resources and arrive at a relevant context almost instantly in some cases, achieving what is known as maximum density, where the best combination of resources is mobilized for a particular context (Lusch, Vargo & Tanniru, 2010; Normann, 2001). This is achieved not only through liquification, but also through innovative information processing and knowledge engineering algorithms that can be executed on demand (e.g., Benaroch & Kauffman, 1999; 2000; Gruber, 1995). In the IoT, liquification further enhances the capacities of digitized objects. Intelligent sensors could provide precise real-time information about the involved devices and integrate with wireless sensors networks to better track and trace things in real time (Da Xu, He & Li, 2014). In the IoT, each physical object has a rich set of data on current and historical information about that object's physical properties, origin, ownership, and sensory context such as the temperature at which a milk carton is being stored in the fridge (Welbourne, Battle, Cole, Gould, Rector, Raymer & Borriello, 2009). For example, a toilet manufacturer, through embedding a sensor in its offerings, is able to 'liquefy' and liberate information about the state of the urine, which can serve as an information resource to be analyzed, stored, or shared on the person's wellbeing. This implies that the company is now able to create new software offerings in the health and wellbeing economy and indeed, derive revenues from the information resource that could complement or even replace the revenues received from selling toilets. With the IoT, and more liquification of information resources, such disruptions are set to increase. Liquification, and the subsequent processing and analyses of informational resources to support decisions and actions, is the fundamental driver of the 'smart' movement in the IoT.

2.2 Internet-of-Things as Digital Materiality

Closely related to the first conceptualization is the characteristic of the IoT as the digital materiality exhibited by the physical objects (Yoo, et al, 2012). Physical materiality entails what a physical object can do. For example, clothes have physical materiality because they can be worn, but are difficult to be converted into a cup when you need one. Also, the consumption and experience of the physical carry social meanings. Digital materiality refers to what the software embedded in the physical object can do by manipulating the digital representation of the physical object (Yoo, Boland Jr, Lyytinen, & Majchrzak, 2012). For example, clothes with sensors have digital materiality in that they can record representations of their use in a digital format. With the IoT, everyday physical objects such as cars, fridges, and watches can therefore be embedded with digital technology such as software, RFID, and sensors to achieve new functionalities (Guinard, Trifa, Mattern, & Wilde, 2011). The IoT would thus enable the harvesting of real-time information of the objects, the interactions, and the environment as well as potentially allowing actuation of such objects. Equipped with digital materiality as described by Yoo, Lyytinen,Boland, Berente, Gaskin, Schutz, & Srinivasan (2010), such objects could possess seven properties: '*senseability*' as the ability of a digitalized artefact to sense and respond to changes in its environment, making it context aware; '*addresseability*' and '*traceability*' as it can be identified and located in real time; '*associability*' as it can be associated, and therefore coordinated, with other objects to enable inferences about future states and conditions; *'communicability'* as the ability of a digitalized artefact to send and receive digitized messages; *'programmability'* as the ability of a digitized artefact to accept new sets of instructions and to modify its behaviors; and *'memorability'* as the ability to store information and historical logs of its state and interactions. Yoo suggests that digital technologies could enable designers to expand existing physical materiality by embedding it with software-based digital capabilities (Yoo, et al, 2010; Zammuto, Griffith, Majchrzak, Dougherty, & Faraj, 2007). This characteristic is crucial for achieving the high resource density for value creation elaborated upon previously. In particular, the six properties of objects with digital materiality would enable the firms to trace, communicate with these objects, and monitor these physical objects by exploiting their senseability and memorability. More importantly, the programmability would enable the firms to add new instructions and modify their behaviour in the whole life cycle of these objects. These characteristics and properties would further enhance the modularization, liquification process to form the assemblages for value creation in different contexts which we discuss below.

2.3 Internet-of-Things as Assemblage or Service System

The notion of resource density through decomposing and reconfiguring the system in the IoT and creating digital materiality of Internet-connected constituents or ICCs (the first two conceptualizations above) would propose the view of the IoT as an assemblage at a systemic level. IoT as an assemblage was first discussed by Hoffman and Novak (2015) in their conceptualization of consumer IoT. Assemblage theory was developed by DeLanda (2006) to describe systems characterized by relationships of externality as alternatives to organic totalities. According to DeLanda (2006), "a component part of an assemblage may be detached from it and plugged into a different assemblage in which its interactions are different" (p.11). Hoffman and Novak (2015) applied the notion of assemblage to the consumer IoT context.

Simply speaking, assemblage refers to objects/devices working together and in this process, the ability to do things that none of these objects could perform on their own (Hoffman & Novak, 2015). Hoffmann and Novak (2015) describe assemblage in consumer IoT as "a collection of heterogeneous components that interact with each other: within-assemblage (component-to-component); part-whole (component to assemblage) and between-assemblage (assemblage to assemblage)". By applying the distinctions between property, capacity, and tendency made by DeLanda (2006), Hoffman and Novak (2015) emphasize that the IOT assemblage is constantly changing, constituents can be removed or added, and that they exhibit three characteristics: the *properties* (a defining characteristic of a component: making a finite list; "what it is", p.41), *capacities* (the activated/exercised properties in the assemblage; "what it can do", p.42), and *tendencies* (what an assemblage can become). Hoffman and Novak (2015) stress that "through on-going interaction of components, new capacities can emerge" (p.42), and they use a door lock as a case to illustrate consumer IoT. For example, a door bell/lock could be an alert device. When connected to the Internet and to the camera, the doorbell/lock and camera assemblage enables the homeowner to see who is at their front door and to speak and interact with the visitor, even when they are not physically at home (Hoffman & Novak, 2015). The door bell/lock on a greenhouse and the temperature sensor assemblage would enable the remote control of the opening and closing of the door. This characteristic of IoT would be crucial for freely decomposing and reconfiguring of actors in the IoT.

Thus, the basic principles of assemblage theory is the conceptualization of IoT as a 'whole' that is more than the sum of parts, and the identity of the whole is constructed by its constituents and emerges from the ongoing interactions among its heterogeneous constituents (DeLanda, 2002; 2006; 2011; Hoffman & Novak, 2015, p.41). Assemblage theory derives from systems theory (Bertalanffy, 1968), and other researchers have also used systems theoretic principles and applied them to the IOT as a human-centric smart service system (Leminen, Westerlund, Rajahonka, & Siuruainen, 2012; Ng, 2010; Ng, 2014) and the need for new methodologies and research to study the 'whole', since the assemblage, or system, as more than the sum of its parts, is irreducible to its parts (Spohrer, Maglio, Bailey, & Gruhl, 2007; Ng, Maull, & Yip, 2009; Ng, Maull, & Smith, 2011). Research into service systems have also highlighted the need to empirically investigate system-theoretic constructs such as boundaries, variety, agency, emergence, and value of a service system (Ng, Badinelli, Dinauta, Halliday, Löbler, & Polese, 2012).

2.4 Internet-of-Things as modules, transactions and service

The best combination of resources for a particular situation entails the understanding of what resources are needed and exchanged to be available to the situation. The IoT can therefore be further conceptualized as architectural modules related to the notion of modularity. Baldwin (2008) considers consumer routine consumption practices as taking place in a task network involving 'nodes' ('task-cum-agents') and 'links' ('transfer of material, energy and information' between 'tasks' and agents'). These agents could be human, objects, and/or digital agents who possess skills, information, and material. More importantly, transactions occur within this task network, involving interactions and transfers of skills, information, and material between these agents. Baldwin defines transactions as "mutually agreed-upon transfers with compensation within the task network" whose function is to divide one set of tasks and others (Baldwin, 2008, p.156). These sets of tasks could therefore be deemed as modules. In Management literature, modularity theory proposes that a module consists of a group of elements that are interdependent within itself, but with less dependency between modules. Interactions within a module have high interdependency and 'thick crossing points', and therefore no linear or sequential process can be mapped. For example, what happens in a kitchen between two chefs are highly interdependent interactions. Thus, this kitchen can be considered as what Baldwin would call a transaction-free zone. Transaction locations are likely to be discovered at the module's boundaries rather than within them (Baldwin, 2008). Thus, constituents of IoT can be viewed as modules with capabilities that could converge and diverge to create '*thin crossing points*' i.e. a boundary and a transaction between the modules' tasks for both the consumer and the producer, by dividing skills and competencies. Individuals could modularize their practices as tasks for the design of thin crossing points that allow for new resources (e.g. Internet-connected constituents) to be brought in and for new transactions to occur (Ng & Wakenshaw, 2014). Modularization in consumer experiential spaces can therefore lead to ways where latent needs could be discovered and fulfilled through new offerings. Such a conceptualization of IoT provides a framework for practice and research to design new constituents and boundaries where transactions can be created for resource integration in contexts. Due to the high variety of contexts, how firms could service contexts and achieve scalability would be a challenge . In Operations Management literature, modularity is the means through which "interfaces shared among components in a given product architecture are standardised and specified to allow for greater reusability and commonality sharing of components among product families" (p. 234, Voss & Hsuan, 2011). Modularity can therefore lead to opportunities to outsource modular components and allow a combination of design flexibility and scale economies. This represents a "hierarchy-of-parts" frame, a schema that views design processes as acts of decomposition and aggregation to achieve architectures that preserve and enhance a hierarchy of loosely-coupled parts (Henfridsson, Mathiassen, & Svahn, 2014, p.28). Such a disintermediation and fragmentation of the physical product is useful for reconfigurability to contexts and provide the consumer with better personalization and tailoring of the product to its use (Ng, Scharf, Pogrebna, & Maull, 2015).

The combination of the four IoT conceptualizations implies the creation of a set of capabilities of the IoT on two levels.

On the level of the ICC as the unit of analysis, liquification and resource density results in **identifiability** and **connectivity** between ICCs. With digital materiality, ICCs are capable of **virtual representation and accessibility** for **remote locating, sensing, and operating**. Both liquification and digital materiality combine to create **real-time data/information flows** that could be algorithmically engineered to create intelligence, 'smartness' and augmentation of the ICCs be they objects (e.g. robots) or humans (e.g. cognitive assistance). On the level of the network or system as the unit of analysis, the IoT as assemblage suggest that the augmentation can be a system-level property e.g. a smart home or city that allow a **greater variety of outcomes to be achieved** (augmentation) e.g. an IoT home is not merely an abode but can be a wellbeing and healthcare-enabled environment to serve the elderly. The IoT as modules and transactions result in resources being able to enter and leave the system with greater ease. This implies that the augmented system can respond dynamically to changes in the environment, creating **greater agility**.

We therefore propose a formal and integrative definition of the IoT as *a system of uniquely identifiable and connected constituents (termed as Internet-connected constituents) capable of virtual representation and virtual accessibility leading to an Internet-like structure for remote locating, sensing, and/or operating the constituents with real-time data/information flows between them, thus resulting in the system as a whole being able to be augmented to achieve a greater variety of outcomes in a dynamic and agile manner.*

3. Implications of the IoT

It is clear that the IoT will impact on both consumer and industrial sectors. Within industrial contexts, the IoT is already making substantial headway in revolutionizing industry. It is combining the global reach of the Internet with industrial capabilities to control, coordinate, and manage the physical world of goods, machines, factories, and infrastructure, in a way that will impact existing industries, value chains, and business models.[3] In this paper, however, we will focus on consumer IoT, rather than industrial IoT.

We argue that an era of digital connectivity is putting paid to the age-old debate within the Marketing community; the "goods versus services" conceptualization. Rust and Huang (2014) have also proposed that this is no longer a useful notion. And while academics continue their debate, the world moves into an era of IoT where physical objects, through material science technologies, have morphed from static products into fluid, dynamically reconfigurable, engaging service offerings that can incorporate consumer customization. Human service activities, conversely, are taking on physical tools and forms (e.g. iPads) to create greater efficiency for faster and more consistently replicable services, resulting in cyber (software and sensors) layers becoming more entangled and inseparable from both physical things and humans.

Conceptualizing a physical or cyber offering in the form of an indirect service provision is a more useful logic provided by Service-Dominant Logic (Vargo & Lusch, 2004, 2008), which proposes that all offerings act as a service, a set of applied competencies or capabilities. A future of IoT will see an assemblage of socio-cyber-physical offerings where the combinations of competencies will mean better service in context and on demand, maximizing resource density (Lusch et al., 2010). Integrating that assemblage with a proliferation of consumer data would not only create resource density, but also personalized density (cf. Rust & Huang, 2014). Indeed, Ostrom, Parasuraman, Bowen, Patrício, Voss, & Lemon (2015) have highlighted the need to research into building adaptive and flexible service systems to respond to dynamic environments. An era of IoT would compel researchers to rise to that challenge.

In addition to flexible service systems, platform thinking (e.g. Baldwin & Woodard, 2011) could also be employed in understanding IoT offerings. Platform thinking enables the design of IoT offerings to achieve scalability through standardization of the core components that exhibit low variety, as well as personalization of the offering by providing the peripheral components with high variety (Tushman & Murmann, 1998; Baldwin & Woodard, 2011). The peripheral components could vary in cross section and change over time (Baldwin & Woodard, 2011, p.23). Consumers could augment the peripheral components of the products with a cyber layer to meet their emergent needs in their contexts even with embedded standardized core components. This is fully achievable because offerings could have new capabilities that are dynamic, even after a product has been designed, manufactured, and sold (Yoo, Boland & Lyytinen 2012, p.1399). A seemingly paradoxical statement of 'Every iPhone 6S is identical and every iPhone 6S is unique' spells out the holy grail of physical products in an era of IoT, achieving both economies of scale and scope. Given the arguments we have put forward, we propose that an era of IoT would evolve physical goods into *dynamic service platforms.*

[3] http://www3.weforum.org/docs/WEFUSA_IndustrialInternet_Report2015.pdf

The next part of this paper discusses the implications of IoT on Marketing research. A Marketing focus on an era of IoT is needed because not all IoT technology is adopted by users, regardless of how amazing they may seem. Those that do become accepted would have undergone a process that has traversed fundamental Marketing principles – the technology met a consumer need, and the firm was able to create an offering from that technology, resulting in a purchase decision. These decisions led to production and transactions that were viable for the firm as well as fulfilled demand from a market. The technological offerings then become institutionalized solutions and widespread use ensue (Vargo & Lusch, 2016; Vargo & Akaka, 2012). In other words, it wasn't the technologies in themselves that created their widespread use and adoption, but the markets through which they were offered and accepted. Without market mechanisms, technology would flounder in the backrooms of laboratories or languish in the garages of creative individuals. It is therefore imperative that Marketing takes an active interest in this space. We propose that the IoT is a step change for research in Marketing but one that poses a challenge, in that the most relevant questions would be inclined towards research at the interfaces between Marketing and at least one other discipline. This would require academics to embark on interdisciplinary research and therefore embrace all the risks for which it is known (Stokols, Fuqua, Gress, Harvey, Phillips, Baezconde-Garbanati, et. al, 2003a; 2003b).

To understand the impact of IoT on Marketing research, we continue from the above definition of the IoT (derived from the original conceptualizations). Figure 1 summarizes the key points from the IoT definition and the four implications derived. Each of these will be elaborated below.

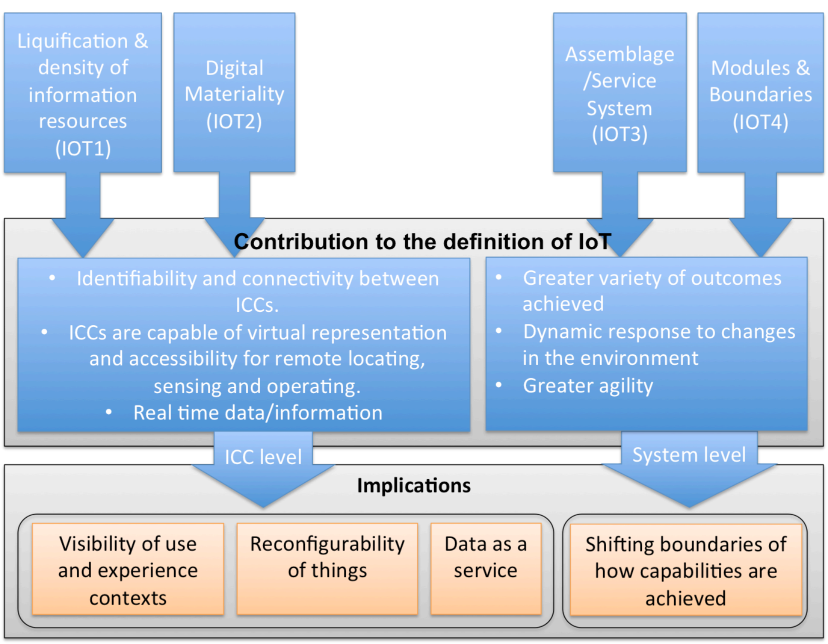

Figure 1: Conceptualization, definition and implications of the IoT

3.1 Visibility of Day-to-Day Contexts/Situations

When everyday objects can be augmented with RFID tags and intelligent sensors to become ICCs, real-time data flow can be automatically produced. Such objects would also be able to generate regular updates and send out large quantities of data, not merely about its operations but also its state and the environment within which it operates; its digital representation, as conceptualized in IoT2. Metadata is data about data. A spreadsheet file on a computer may have content data but the information about the file, such as the date when the file was edited, its size, and storage location, is metadata. A world of ICCs can carry chunks of metadata that, when analyzed, would make sense of their local situation and context. Metadata provide the ability to sense, log, and interpret what's occurring within objects and the world resulting in the liquification of information, as conceptualized in IoT1. In addition, sensors and sensor networks can detect human emotions and generate experiential data. The devices that generate emotional data could be 'affective wearable'; a system that recognizes its wearer's emotions (Picard & Healey, 1997), or 'bio-sensor'; sensors for bodily reactions such as muscle activity, skin conductivity, temperature, blood volume pulse, etc. that can deduce the user's emotional state (Haag, Goronzy, Schaich, & Williams, 2004). An era of IoT could potentially provide visibility of experiential and consumption contexts that hitherto have not been possible. For example, pilots from the hubofallthings.com (HAT) project instrumented a bathroom to collect data on the use of shampoo, toothpaste, shower gel, and even toilet paper where the data is controlled and shared by consumers themselves (Speed, 2014, Parry, Brax, Maull, & Ng, 2016). We propose that this visibility into day-to-day contexts would impact on three broad areas of Marketing research; the consumer experience, dispositions and situations, and behaviors and decisions.

3.1.1 The Consumer Experience

The instrumentation of objects and the liquification of information resources from normal physical objects will add a new dimension to the way Marketing studies consumption and experience. For Marketing research, where previously physical product consumption would occur in consumers' private spaces, an era of IoT would usher in a substantial amount of quantitative data on consumption and experience. This would create a dimension of visibility where none had previously existed, particularly with information on consumption quantity and depletion for particular contexts, interactions between things and between people and things, and information about the environment (Parry et. al., 2016).

Marketing has endeavored to gain insight into how consumers experience the products they purchase. Research into consumer experiences today is often acknowledged to be divided, with one side focusing on information processing models to predict consumer behavior and the other side on consumer experience research, such as Consumer Culture Theory (CCT). Research into information processing models of consumer behavior have used methods such as experiments, surveys, and focus groups to understand how consumers feel about their experiences and the emotional associations (Berry, Carbone, & Haeckel, 2002). CCT has represented the endeavor to study consumer experience, which has developed into an independent discipline to specifically explore consumption and experience in "its full experiential and sociocultural scope" (Arnould & Thompson, 2005, p.870). Some have conceptualized consumer experiences as consumer 'touchpoints' (Meyer & Schwager, 2007) and consumer 'experience clues' (Berry et. al, 2002) that provide ways to understand the data/information required to better manage consumer experiences.

Clearly, IoT data would not supplant the rich and meaningful narratives as those generated from research methods used in CCT. Indeed, it is commonly acknowledged that consumer experience is subjective, personal, and engages at different levels; rational, emotional, sensorial, physical, and spiritual (Gentile, Spiller & Noci, 2007, p. 397). However, a heightened level of visibility from a data perspective, including visibility of direct experiences during a specific interaction with an Internet-connected constituent; a 'momentary experience' (Roto, Law, Vermeeren, & Hoonhout, 2011; Hoffman & Novak, 2015, p. 81), turns the physical product experience into one of service (Hui and Bateson, 1991; Edvardsson, Enquist, and Johnston, 2005; Patrício, Fisk, and e Cunha, 2008; Patrício, Fisk, and Constantine, 2011). This service experience offers new insights into the emerging value creation and value-in-use (Ng & Smith, 2012; Holbrook, 1999; 2003). More importantly, the relationship between the consumer and the firm also evolves into a service relationship with experiences that are co-created, inseparable, perishable, heterogeneous, and intangible. Lessons from more than 40 years of service research could inform the new world of Internet-connected product experiences.

3.1.2 Dispositions and Situations

The visibility of consumption experience in an era of IoT would lead to another major impact on Marketing research, that of shifting the unit of analysis from *disposition to situation*. It has also been acknowledged that behaviors are spurred both by disposition (personal traits) and **situation** (contextual traits) (Nisbett, 2015; Ross & Nisbett, 2010; Gawronski, 2004). Both have been identified as the key factors affecting predictability of social behavior and behavioral consistency (Snyder, 1983). For example, the fact that an individual might like his coffee black with no milk could be dispositional, because he could be lactose intolerant. However, how much sugar he has with his coffee is situational, with sugar in morning coffees and none in afternoon coffees, depending on his recommended sugar intake for the day. However, traditionally influenced by economics and psychology, the driving forces of research in consumer decision-making is that of **disposition** i.e. personal traits, whether cognition or affect, and/or whether the consumer is rational or otherwise. Thus, research into dispositions/personal trait are well understood. Nonetheless, despite recognition of situational factors in research (Belk, 1974; Brandstätter, 1993; Van Raaij, 1981), they have been under-researched. There is evidence showing that traditional dispositional approaches to predicting consumer behavior have been disappointing (Kassarjian, 1971). This is because situational factors may have more impact on behavior (Belk, 1974; Becherer & Richard, 1978).

We argue that most research have privileged dispositional rather than situational traits. In an era of IoT, information and visibility of consumers' actual behaviors and consumption routines (buying, consuming, storing, disposing) would become increasingly available. The IoT would make available the visibility of the user's connections and interactions anytime, anyplace, with anything and anyone, any network, and any service (Vermesan, Friess, Guillemin, Gusmeroli, Sundmaeker, Bassi, Doody, 2011). The availability of sensors would bring forward a new set of dispositional-situational parameters that makes 'verb' parameters such as "waiting" for a bus or "eating" a meal an operationalizable and measurable construct, together with other social and environmental parameters such as location, weather, temperature, and air quality.

3.1.3 Behaviors and Decisions in Context

The availability of new measures would open new horizons in Marketing research for those investigating consumer behaviors and decision-making. The IoT is being used to create behavioral "nudges" i.e. the application of findings from psychology and behavioral economics to prompt individuals in normal day-to-day situations into making decisions that are consistent with their long-term goals (Burgess, 2012). Indeed, we see that new measures in the IoT would enhance research focusing on transformative service, centering on individual and community wellbeing to achieve better quality of life for consumers and society as a whole (Ostrom, Bitner, Brown, Burkhard, Goul, Smith-Daniels, Demirkan, & Rabinovich, 2010; Anderson & Ostrom, 2015). Researchers in location-aware marketing (LAM) have already proposed that marketers can reach mobile consumers through their mobile devices with personalized marketing messages delivered to consumers based on their geographical locations and the prediction of their needs (Xu, Luo, Carroll & Rosson, 2011). Clearly, these research questions sit within the Marketing domain, but overlap substantially with Information Systems, Data Science, and Behavioral Economics. With the IoT, the visibility of consumer experience, environment, contexts, and interactions in contexts could reveal real behavioral patterns and routines that would move Marketing research into new methods of obtaining data. Empirical studies can be conducted in various ways. Research could instrument real spaces such as homes or shops for experiments, or through the creation of specialized software, requesting individuals to contribute their data to the research. All types of actual data from emotions, pulse rates, location, can be volunteered and collected. Where previously, such data would be held by firms and thus less accessible by researchers, an IoT world of open APIs means that software created to pull data directly from consenting data donors is now possible. Marketing researchers in an era of IoT can finally understand consumer behavior in a way that was not possible previously.

Visibility of contexts would drive a new research agenda in behavioral aspects of consumption and experience. We propose three research priorities:

- *Integrating goods and service-based models of consumption and experience*
- *Developing new dispositional-situational models of behaviors*
- *Understanding and influencing behaviors and decisions in context*

3.2 The Reconfigurability of Things

Service-Dominant Logic scholars conceptualise service as using the knowledge/skill for the benefit of the beneficiaries and hold the notion that there is no division between product and service (Vargo and Lusch, 2004). Firms provide affordances for users to choose and act upon and form an assemblage (service system) for value co-creation in contexts. In the era of IoT, the physical offering has the potential of not being static. Physical products can now be designed to be changeable, for example through an application interface that allows customizability upon use to respond to emergent contextual situations, or with a sensor that can change the physical product function based on some intelligence, as conceptualized in IoT2. Consequently, consumer needs and wants can be fulfilled not merely with physical products but with combinations of the physical and the digital, personalized with consumers' own data. One example is the smartphone, which is a 'functionally-incomplete' offering upon purchase because consumers need to install applications and enter their own data to make it fully functional. For consumers, this functional-incompleteness remains over the product's whole life cycle so that it could be re-personalized over and over again for different use contexts (Yoo et. al, 2012).

In addition, a single object that becomes an ICC essentially becomes part of a whole, as conceptualized in IoT3 and thereby is able to achieve greater outcomes. Singular objects becoming ICCs evolve into what we term as a **dynamic service platform**. It is dynamic because the material and digital technology allows for reconfigurability and mobility and it can be experienced wherever the consumer wants it; a service because it will apply its competency to co-create value with the consumer (Vargo & Lusch, 2008); and a platform because it can allow consumers themselves to better tailor their experience of the product to their own contexts and customize its functionality through their actions (Cova & Cova, 2012). The core elements of an IoT platform, as conceptualized in IoT4, is the software platform including a set of reusable components, modules, and other building blocks that have comprehensive sets of application-dependent functionalities (Wortmann & Flüchter, 2015, p.222) that can be used to build IoT applications and products (Mazhelis & Tyrväinen, 2014; Wortmann & Flüchter, 2015). Since a product dictates a template of behaviors, as Yoo et al (2012) calls it, it is imperative that Marketing research adapts to this new era of connected products which would have impact on three streams of research; product design, differentiating the product, and payment/consideration models.

3.2.1 Product Design

Upstream marketing is a term used to describe Marketing's participation in the firm's 'upstream activities', such as product development. Upstream marketers are involved in '*customer sensing*' (Kotler, Rackham, & Krishnaswamy, 2006) i.e. they monitor the voice of the customer, consider customers' goals and outcomes, and discuss the 'jobs' that consumers want done in their lives (Christensen, Anthony, Berstell & Nitterhouse, 2007). Upstream marketers develop a strategic view of the firm's opportunities and threats, and share their insights with senior managers and designers. The IoT's ability to reveal situations and contexts provides an opportunity for Marketing to be more closely involved in upstream marketing, and more specifically in the design of an offering (good or service), both physical and financial.

Marketing has a long tradition of product research predominantly in two areas - design/innovation and differentiation. The focus of product design is to define the offering's properties in terms of form and function (Luchs & Swan, 2011). Product innovation involves many phases from idea generation through to launch (e.g. Hauser, Tellis, & Griffin, 2006; Luchs & Swan, 2011). In the IoT, the spatial and temporal division between design, production, and consumption of offerings is increasingly collapsing into the same space, especially with changeable offerings, informed by data. One way of conceptualizing this space for both sides is to focus research in the design of the offering less on forms and functions and more on *affordances* (Withagen, de Poel, Araujo, & Pepping, 2012). Affordances (Gibson, 1979), as possibilities to act in the environment, have been used by researchers as the basis for designing interactions (McGrenere & Ho, 2000; Pols, 2012). Ng (2014) first used it to understand value-creating interactions in the IoT, discussing affordances as connective possibilities of a physical product, as opposed to its distinctive possibilities. Affordance focuses on the 'action-ability' of products; for example, it's the 'write-ability' of a pen or 'seat-ability' of a chair that focuses the object not merely on itself, but on the assemblage and other contextual resources to achieve the action and goals. The 'functional-incompleteness' of physical offerings result in open and flexible boundaries of such products, in turn allowing consumers to materialize multiple affordances and dynamically modify them to match their competences within contexts, evolving all entities into providing a service (Ng, 2014; Vargo & Lusch, 2008). Designing products as dynamic service platforms imply the need for Marketing to contribute to action possibilities for value creation, fulfillment of latent needs, and could also invite new behaviors. In Economics and Marketing Science, a future preference and/or consumption that is uncertain has been modeled through Knightian uncertainty (the "unknown, unknown") or through state dependency (e.g. Fishburn, 1974; Jacobson, 1990; Shugan & Xie, 2000). Marketing research and models can assist firms in shaping their products even when empirical work is not possible.

If Marketing is serious about its role in "meeting needs, profitably" (Kotler & Keller, 2006) in the era of IoT, it needs to rethink the research into traditional processes of product design and innovation, and Marketing's role within it. In an era of IoT, a new approach is needed. The set of parameters that drive a physical product's design depends on fixing the requirements for functionality and form. Marketing would need to bring situational and contextual insights to bear on these parameters to innovate on future offerings, and on the understanding of how consumer latent needs can emerge new generative offerings (Yoo et. al, 2010).

3.2.2 Differentiating the product

Related to product design is research into product differentiation. With roots in Industrial Organization and Economics (Chamberlin, 1965; Porter, 1976; Samuelson, 1976; Smith, 1956), product differentiation is defined as an offering that "is perceived by the consumer to differ from its competition on any physical or nonphysical characteristics including price" (Dickson & Ginter, 1987, p.5). Interestingly, there has been no new conceptualization on product differentiation over the past 20 years within Marketing. We argue that an era of IoT would require a different approach towards product differentiation, particularly when there is no division between product and service. A product is a dynamic service platform that is tied to variety or flexibility in consumption. For example, Spotify now has hundreds of playlists with music combinations that aim to fit consumer experiential contexts, from 'summer BBQ' to 'bath and soak'. Indeed, consumers regularly purchase assortments of products in the same product category in terms of brands, products or units (Hendel, 1999; Dube, 2004). The rationale is that the assortment would provide such flexibility that would allow the consumer to choose from inventory the option that is most appropriate for a consumption occasion (Walsh, 1995). Such flexibility in consumption is seen as an important attribute for consumers when purchasing.

Since consumers' consumption and experiential contexts can be of high variety, an offering tailored towards multiple contexts may be too heterogeneous and consequently, too costly for the firm to produce (Guo, 2006). Guo (2006) found that firms face a "flexibility trap" in which primary demand increases but profits decrease with greater consumer heterogeneity. Here again, service research offers valuable advice. The tension between 'production' efficiency (and therefore profitability and viability, scalability) and serving customers more effectively in a more personalized way that will lead to higher variety of attributes built into the offering, is a common challenge faced in service literature that discusses core and supplementary services (e.g. Bitner, Brown, & Meuter, 2000; Storey & Easingwood, 1998; Piccoli, Brohman, Watson, & Parasuraman, 2004; Balin & Giard, 2006;). Supplementary services could be used to address variety and core services have allowed the firm to retain some standardization and achieve cost efficiencies.

Where the offering itself cannot be modified, a standard compromise to achieving some scale efficiency and degree of fit is to break down the market to segments of customers and target them with a differentiated offering (Rosen, 1974; Lancaster, 1979; Goyal, 2008; Magaldi & Crescitelli, 2008; Van Riel, Lijander, & Jurriens, 2001). The downside of such a model is the loss from unserved customers, and the corresponding revenue and profits they bring. The rigidity of pre-specifying customer requirements for the purpose of standardization means the offering (and therefore the firm) is not able to adapt and respond to changes at the consumer usage end when contexts of use, even for the same person, could change. This trade-off is fast becoming obsolete in an era of IoT, as objects can be embedded with a digital layer and become reconfigurable. We argue that it is Marketing's role, as champion of consumers and responsible for the firm's profitability, to shape the boundaries between the configuration of resources/attributes available to absorb the variety for personalization (and therefore allowing consumption flexibility and contextual variety) and the configuration of resources/attributes put in place for standardization. If personalization resources are digital in nature, microsegmentation can be achieved since digital technology supports design flexibility across the product life cycle (Henfridsson et. al, 2014). Under IoT2, Yoo calls this a “procrastinated binding of form and function” (cf. Zittrain 2006), analagous to supply chain's concept of postponement in mass customization (Yang & Burns, 2003) where new capabilities could be added even after a physical product has been produced and sold. Smartphones and their apps are a case in point for attribute personalization and product differentiation through self-configuration and self-selection (cf. Moorthy, 1984). Yet, even for the iPhone 6S smartphone, Apple needed to produce two sizes, suggesting that personalizing the attribute of *size* is still technologically unattainable and remains as a differentiating factor.

3.2.3 Payment/Consideration models

Research is also needed not merely in the design of the offering but also that of the payment or consideration model. Where a product’s form and functionality is not static, the consumer's willingness to pay is therefore uncertain and consequently, the type of consideration itself is a design issue. Marketing research have acknowledged that digital services need to identify new monetization strategies for assets that have not traditionally been viewed as such; for example, traffic (i.e. visitors to a website) (Mallapragada, Grewal, & Lilien, 2012), content (Zhang & Katona, 2012), and eyeballs (i.e. users seeing adverts) (Zhu & Wilbur, 2011). However, the mechanisms for generating money from these assets and indeed, other informational assets, have not been fully explored. According to Bradford (2015), money in Marketing is still under-researched. Yet, the appropriate choice of a payment or consideration model can have a significant impact on a customer’s willingness to pay and therefore revenues to the firm (Carter & Curry, 2010). However, much of Marketing literature around both financial and non-financial exchange tend to focus on platforms (as the manifestation of two- or multi-sided markets). Even then the emphasis seems to be on which customer group to focus on, rather than the exchange and consideration model. Others have focused on which methods to use (Sridhar, Mantrala, Naik, & Thorson, 2011), or they model the pricing strategy decisions by the firm as an exercise in information asymmetry or risk aversion (Liu & Viswanathan, 2014). IoT2 (liquification) can provide a way to understand what potential resources (information and material) are required for each ICC in the system; what skills and competencies are transferred between whom and how they are transferred; and how the tasks could be divided into sets of tasks and the consideration for each transfer or transaction. For example, a train carriage can be described as having 50 seats, with 20 empty seats. Such a description could be liquefied through sensors and the information resource created can be shared with potential passengers at the next station by having it sent over the Internet through a mobile application. As a replicable, scalable digital resource with almost zero marginal cost, information about the train could potentially be exchanged, creating a new revenue stream for the rail company. Taken to its extreme logical end, train passengers may not even need to pay for their journey, if revenues from information resources surpass associated costs. On the Internet, such business models of exchanging and transacting on data and information are common (e.g. Google, Facebook etc.), and consumers often obtain ‘free’ services as a consequence. While this may be alarming for some, there is no reason why such models cannot creep into the physical world in an era of IoT. It is now possible to have an environment that enables networked actors in the IoT to efficiently share basic information with one another in real-time in a physical space (Yang, 2014). Transactions can be held for offerings not related to product function but description (the metadata) where they can also create value, as in the case of the toilet manufacturer with the sensor. With an understanding of the transaction boundaries and the possibility of dynamic re-configurability and flexible boundaries of products, different offerings can be designed for various contexts and consumers.

The reconfigurability of things brings Marketing into the conversations around product design and matching it with consumer experience and needs and finally, the consideration/payment for the offering. Three topics of research priorities are proposed:

- *Designing physical and connected products and platforms for better digital service experiences*
- *Developing new differentiation models with reconfigurable physical and connected products*
- *Creating new payment/consideration models for physical and informational offerings*

3.3 Data as a Service

An era of IoT will generate a massive amount of data. Data storage capabilities and computing speed have enabled data collection at an unprecedented scale, allowing different types of data with different structures and models to be stored in big, and sometimes distributed, storage systems - commonly termed as 'big data'. Cloud computing solutions can now handle data analysis with great speed and increasing flexibility across time and space (Rust & Huang, 2014). This in turn enables every object from hair dryers, TVs to fridges and car keys to be connected. This implies that real-time consumer generated data from objects will be dominating the IoT, leading to the ability to create real-time on-demand responsive service from data. A recent paper from Parry et. al. (2016) provided four measures of real-time consumer IoT data – consumption, depletion, interaction, and experience. These four categories of use visibility measures [UVMs] address the main dimensions of consumers' use of resources (Parry et al., 2016): depletion resources are consumed at a rate faster than replenishment e.g. food; consumption resources are replenished at the rate of consumption e.g. water, gas, Internet; experience resources are diminished but not depleted during single use e.g. towels, cups; and interaction resources are not diminished during single use such as doors, floors etc. A sample of the data is in Figure 3. This suggests that a combination of IoT data and knowledge engineering algorithms could provide real-time understanding of when a need occurs and how to fulfil it through recommendations, on demand.

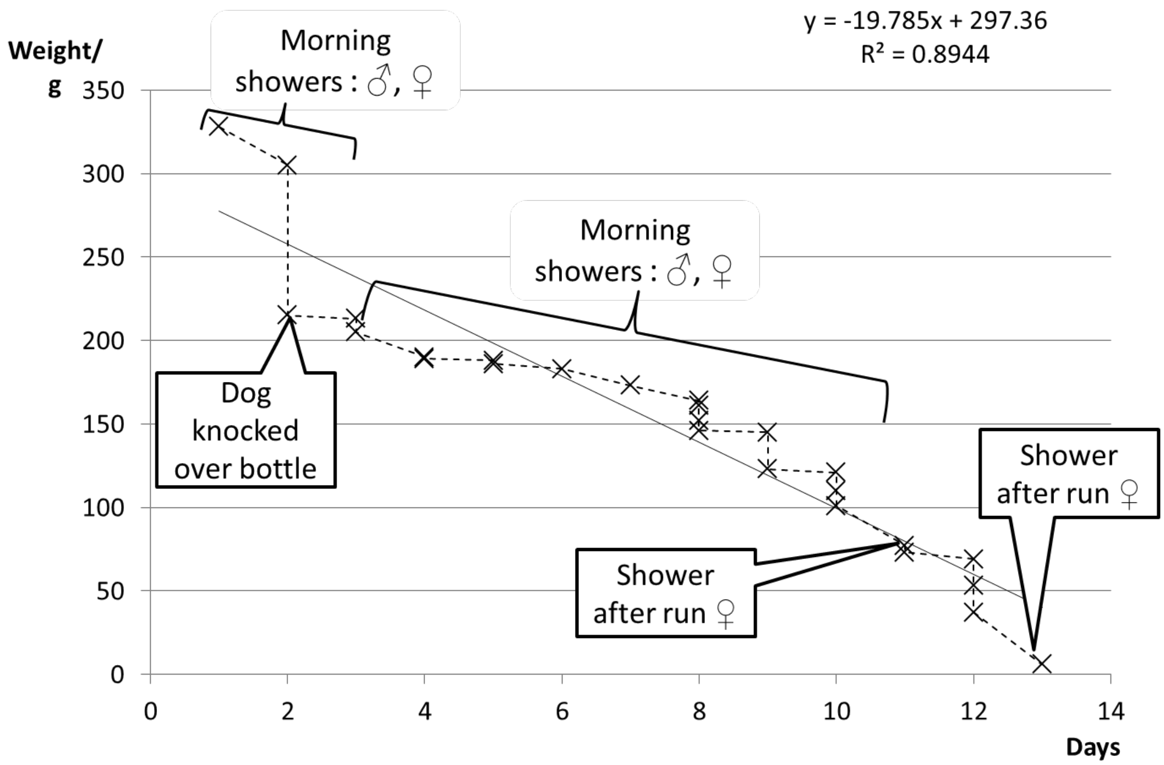

Figure 2: Weight of shower gel container (from Parry et. al., 2016)

As conceptualized in IoT1 and IoT2, both data that create digital representations and information flow and that is formed through liquification and density will allow a company to be much more agile than its competitors and take advantage of new market opportunities more quickly, or respond to consumer needs almost instantly. This is aided by an explosion of organizations releasing open APIs (Application Programming Interface). An API specifies how software components should communicate with one another in a way that is agnostic to whatever programming languages the software was built on. A good API makes it easier to develop programs by providing building blocks for programmers to put together to create digital services. It is suggested that APIs would create a native language for communication, which makes it easier to exchange data and become an enabler for interoperability[4]. In the IOT, the API economy is beginning to gain traction and firms are exposing data from their internal assets, services, and competences/skills and even the data from IOT products they sell, through APIs to other entities in a system to create network effects and to take advantage of the IOT assemblage for value creation through data sharing.

[4] http://searchhealthit.techtarget.com/feature/APIs-in-healthcare-Possible-use-cases

We argue that in an era of IoT, the transformation of data into information, both for the firm and the consumer, is a critical research agenda. What needs to be taken into account is the use of the data as well as its transformation into information that may need to be integrated with other datasets, and be made usable by firms and consumers i.e. *data being a service*. The challenge of transforming data into an information service has an impact on two major streams of research; personalization and vulnerabilities.

3.3.1 Personalization

The most powerful, and yet most contentious aspect of big data in an IoT world, is that of personal data. With so many products now connected to the Internet, generating data on their use, the amount of personal data being collected from devices that are connected, embedded, and invisible in the everyday lives of consumers is reaching staggering levels (Overby, Slaughter, & Konsynski, 2010; Perera, Zaslavsky, Christen, & Georgakopoulos, 2014; Mitra & Ransbotham, 2015). In an era of IoT, personal data is fast becoming an externality (Baumol, 1972) that is both positive, in that firms are able to better serve customers on demand, as well as negative, in that individuals are beginning to become concerned about the privacy, security, and confidentiality of their own data, especially when combinations of their personal data held by different firms could not merely identify them, but reveal sensitive information as well (Malhotra, Melville, & Watson, 2013; Cecez-Kecmanovic, Galliers, Henfridsson, Newell, & Vidgen, 2014). Yet, obtaining new practical insights into personal data represents one of the most important and compelling areas of opportunity for the digital economy, and is a research priority. In its 2012 report 'Unlocking the Value of Personal Data' (WEF, 2012), the World Economic Forum urged firms, customers, and policymakers to unlock the economic and social value of personal data in ways that will encourage innovation, gain new insights, and make better decisions without diminishing the rights of the individual. The value of this industry across Europe was estimated to be €1Tn annually by 2020.

We argue that there is a need for Marketing to research and understand *where and how* consumers are able to use their own data and create value with it, and firms are able to use the data as well to personalize their offerings. This implies that data about individuals must be accessible to them. The current model of the data economy is one where the firm that collects the data has the custodial right (i.e. the right to give rights) to it (Skilton & Ng, 2016). This data is collected often with very little knowledge of contexts, such as knowing where the product was used. Personal data collected within this industry silo-ed type model is conducted by firms for their own benefit and purposes. For example, consumer purchasing data helps supermarkets tailor vouchers and promotions and optimize the supply chain of their goods. This means that the format and organization of the data was created to suit the firm. So even if consumers have access to the data, they may not have the ability to process, manipulate, and make the data useful for themselves. In addition, the sharing of such data with other firms, even for innovative new offerings, is often constrained by privacy laws. In response to this firm-centric structure, computing and human-computer interaction or HCI research have called for the need for a personal data repository (Mortier, Haddadi, Henderson, McAuley & Crowcroft, 2014, Perera, Wakenshaw, Baarslag, Haddadi, Bandara, Mortier, Crabtree, Ng, McAuley, & Crowcroft, 2016), as it is becoming evident that it could be beneficial for us, as consumers, to have access to our own personal data. However, this has had limited success for three reasons. First, the 'vertical' data acquired and stored is not organized and structured for decision-making as it is oriented towards the firm's decision support, rather than for consumer use (Schlichter & Kraemmergaard, 2010). There must therefore be a level of transformation where such vertical industry data can be transformed into a 'horizontal' (Yoo et al, 2012) structure so that the data can be organized to aid human decision. Abowd, Dey, Brown, Davies, Smith, and Steggles (1999) pose the challenge as a lack of a taxonomy and understanding of contextual types for the understanding of personal data. Second, even if the data is transformed, there is currently no platform through which the individual can access/buy and therefore use further computational capabilities to analyze and use their own data (Abowd et. al, 1999). Finally, we argue that keeping personal data without the possibility of an exchange is analogous to keeping cash under a mattress. For personal data to have impact on the economy, more research should go towards understanding the means through which the exchange and use of personal data can be beneficial for both the individual and firms (Ng, 2013; 2014). The Internet landscape is set to change, however, with the introduction of the HAT[5], a personal data platform owned and controlled by the user with full custodial rights of personal data movement and exchange. If Internet users begin to have HATs the way they started having e-mail accounts, the dynamics of the marketplace will see a disruptive change that will not only affect Marketing practice and research, but the business environment as well. CRM will evolve into VRM (Vendor Relationship Management), a movement initiated by Searls (2012) who envisaged the VRM as enabling individual customers to perform what organizations can do with their data from collecting, storing, and sharing (Mitchell, Henderson & Searls, 2008, p.4). In such a market, customers/buyers, being able to cast intentions to buy, would find sellers rather than being captured by them. Vendors would respond to such intentions of customers (e.g. a digital shopping basket shared as an open API) rather than guessing what might get their attention (Searls, 2012).

Through a focus on personal data and the context of its use by individuals, there would be opportunities to research into personal data markets that can be established between individuals and firms. The future of segmentation and targeting research in Marketing would benefit individuals through opportunities to buy services that make their data useful in future purchases e.g. matching what they own or consume with what they wish to buy, or to buy services to analyze their own data so as to make better decisions for day-to-day living.

3.3.2 Vulnerabilities

[5] http://hubofallthings.com

While personal data appears to hold great potential for commerce and society, there is increasing concern about the risks associated with its access, ownership, data privacy, and confidentiality, the potential for misuse in social engineering and, very importantly, the transparency of its use and exploitation (Jiang & Landay, 2002). Research is needed to better understand the risks, and the mitigation mechanisms to reduce them. An era of IoT that could thrive on fair digital market exchanges between consumers and firms, stimulating innovation, new jobs, and businesses, would rapidly be snuffed out if individuals withdraw their involvement out of fear, or obscure their own data in protest. This would result in a downward spiral of the digital economy and a breakdown in confidence. This implies that a world of technology, even as it augments some through service and new capabilities, would leave others feeling vulnerable.

A key issue in an era of IoT is that of privacy. While there has been much talk of, and research into privacy, it is less clear how much of it individuals really want and what actions are driven by their privacy concerns (Atzori, Antonio~~Iera~~, & Morabito, 2010; Weber, 2010).

Governments have entered this space with considerable discussion on the regulatory framework for privacy. The policy goal is to protect privacy as an end regardless of economic consequences. For example, current EU Privacy legislations (defining "*mandatory practices and processes for privacy protection",* Zeigeldorf, et al, 2014, p.3) are based on the recognition of privacy as a fundamental human right. The core privacy principles[6] relating to personal data rely heavily on the informed choice model (Rubinstein, 2013), which is based on the individual's ability to personally control the acquisition or release of information about oneself (Froomkin, 2000). Technological advancement has challenged these principles and legal scholars have questioned whether current core principles of informational privacy fit the purpose of privacy protection in an IoT era (Zeigeldorf, et al, 2014; Rubinstein, 2013; Koops, 2014). In addition, some economists challenged against the assumption of human right for personal data protection (e.g., Noam, 1997; Acquisti, 2010, p.7). Indeed, with the continuing advancement of digital technology, the argument for personal data protection has evolved from a human rights concern to an economic rationalization based on the trade-offs between risks and return (Godel, Litchfield, & Mantovani, 2012, p.43). This argument is in line with the self-regulatory framework approach to privacy which advocates a balance between data sharing and data protection to increase aggregate welfare. This framework centers more on markets being self-correcting with the regulators' role as one of steering the market through a combination of incentives, disclosure policies, and even liability (Acquisti, 2010, p.33). Under this framework, individuals must be able to convey their preferences in terms of the use of personal data to other parties; they could be assigned property rights in their perusal information, and they can contract with other parties about how they might use the information (Shapiro & Varian, 1997; Schwartz, 2004, p. 2058.) There are also signs that the idea of a private market for personal information is regaining support (Godel et al,

[6] These core principles include data quality (characterised in terms of purpose limitation, data minimization, accuracy, and completeness), consent, transparency, access, rectification, confidentiality, and security, Zeigeldorf, et al, 2014).

2012, p.46; Novotny & Spiekermann, 2013, p.104). After a series of discussions and consultations, the general data protection regulation (GDPR) was adopted by the EU in April 2016, mandating a new set of rules to be in effect from May 2018, a significant change to the way EU organizations can collect, use and transfer personal data[7].

Aside from state intervention, others argue that privacy is a red herring, and what needs to be addressed is vulnerability. For example, much of physical human activities are performed in public; we go shopping on the high street, sit in the park to read, watch films in movie theatres, etc. In such situations, we are often comfortable being in the public eye, and indeed, we perceive ourselves free to browse, buy or interact even though our actions may not be private. Within the digital domain, many of our activities are also 'public' in the sense that we give away our browser cookies, search for goods and services on Amazon sites, and allow goods and service providers to see what we look at and what we buy. In some cases, we are uncomfortable with this but nonetheless do it under some form of duress, since we are not entirely sure what data about our digital presence we are giving away (Dinev & Hart, 2006). In other cases, we are relaxed about the scrutiny, i.e., we are willing to give up privacy in exchange for rather simple services. All this suggest that individual *perceptions* of privacy and security are strongly affected by two factors: (a) personal attitude towards uncertainty and risk which defines how an individual perceives potential threats, and (b) context (Bansal, Zahedi, & Gefen, 2008).

Current cybersecurity literature tend to address issues of security and privacy through technical solutions such as security protocols and algorithms that 'protect' the individual (Danezis, Domingo-Ferrer, Hansen, Hoepman, Metayer, Tirtea, & Schiffner, 2015). Given its contextual nature, we argue that the underlying driver of *action*s in an era of IoT may not be privacy, but that of *vulnerability*. We argue that research is needed to expand on the understanding of vulnerability in digital domains, and how mechanisms such as perceived control and trust could reduce vulnerability and therefore be built into firms' offerings. Research into vulnerability needs to be considered from three perspectives. First, the individual's perspective of their own vulnerability; second, the perspective of the entity with whom the individual is interacting in the digital domain (which could be another individual, or a firm); and third, the institution tasked to regulate and protect all entities within the system (eg the state, regulatory body etc). All three entities would assess individual vulnerabilities in different ways and would have separate sets of trade-offs against the risks. From an individual's point of view, the trade-off is between the choice/freedom to use a service against the risk of being vulnerable. From the firm's point of view, the individual's vulnerability and assessment of risk is important for its business model and it would trade off revenues and provide additional services to mitigate that risk, but only to the extent that would pacify the user and the regulator. Alternatively, it would become a differentiator. Finally, from a regulator's point of view, the aggregation of large numbers of users and a complex system of data-sharing creates a systemic risk that may result in individual vulnerabilities. The regulatory trade-off is to weigh the risk of inaction

[7] https://ico.org.uk/for-organisations/data-protection-reform/overview-of-the-gdpr/

against policies that would curtail choice and freedom for individuals and firms to interact. The regulator has a further consideration. The risk and uncertainty with regard to the loss of privacy becomes harder to measure especially when individuals' data accounts become increasingly complex. This makes cybersecurity problems harder to predict. Although the risk is systemic, the consequences could be critical for individual users as they may become more vulnerable to cybersecurity threats. Furthermore, vulnerability at the societal level may undermine existing digital institutions as people lose trust in the entire system (e.g., they may eventually distrust all apps if one app provider seriously endangers their privacy and security). We argue that the challenge of vulnerability is therefore a socio-economic-technical one, and that research in Marketing is at the interface of data science and cybersecurity where a technological focus needs to be balanced with an understanding of human perception and customer engagement with a digital service. By entering into this domain, Marketing can inform vulnerability issues through the design of business and economic models; for example, models that allocate risk (and therefore payments) between the customer and the service provider, and those that provide guidance for policy makers on appropriate regulation.

An IoT era will need a greater understanding of the role of data and its interaction with consumers as they evolve from need-driven transactions into an era of data-driven intelligence and decisions. Marketing plays a crucial role in helping firms understand the use of personal data and explore opportunities to design and bundle offerings more suited to the way individuals experience and consume products and services in context, in a more scalable way. Yet, while firms could integrate personal data across silos to develop new offerings, there is a need to respect the rights of individuals and reduce vulnerabilities. We propose that research in this space should take on the following priorities:

- *Innovating on personalised information-based offerings*
- *Understanding and reducing vulnerabilities in IoT*
- *Improving consumer engagement with IoT offerings*

3.4 Shifting Boundaries

The combination of IoT2 (digital representation), IoT1 (liquification), and IoT4 (remodularization) suggests that the transfer of data (and information) between entities and the real-time connectivity between ICCs will result in unprecented levels of cooperation, coordination, and communication. This implies that the IoT would be the most disruptive technological advancement since the World Wide Web, in the way boundaries can shift from current vertically-organized industries to horizontally-connected, platform-driven ones.

An era of IoT fragments the interaction of physical objects into physical, informational, and socially-connected interactions with other individuals and objects. In essence, innovation and markets could also be located in the three interactional spaces. Yet, for these spaces to be useful, some level of structure would be required, giving the impetus to the creation of platforms (Baldwin & Woodard, 2011). Platform literature suggest that modular interfaces could be fixed to create thin crossing points in the network of the relationships in the system and establish the boundaries of modules. It is suggested that modules and modular interfaces in a large system reduce the cost of splitting design and production across multiple firms (Langlois & Robertson, 1992; Sanchez & Mahoney, 1996), as well as coordination and transaction costs (Baldwin & Clark, 2000; Baldwin, 2008). This kind of disaggregation gives rise to the 'modular clusters' or 'business ecosystems' of complementary and competing firms (Iansiti & Levien, 2004; Baldwin & Woodard, 2007; Baldwin & Woodard, 2011, p.23). One critical feature of platforms is the potential creation of network effects, which could be very powerful when there is a direct link between the platform and the user of the complementary innovation, and could be enhanced when there is technical compatibility or shared interface standards (Gawer & Cusumano, 2014). Physical spaces already have such structures, be they markets in a retail mall or online. Social spaces are evolving to establish such structures e.g. on Twitter or Facebook. An era of IoT will push physical and social spaces into hybrid spaces of cyber-socio-physical interactions and create enormous potential for firms to create new platforms. This would have impact on three streams of research; markets, institutions, and economic/exchange models.

3.4.1 Markets

When technology allows firms to move tangentially, not merely in terms of horizontal or vertical integration but across unrelated businesses, the potential for rents to be transferred across industry sectors to gain greater advantage could result in market upheavals. This is already happening with the move of Google (originally an online search company) to Nest (manufacturer of thermostats), competing with GE and other manufacturers in the same space; the move of Amazon (an online retailer) to Prime video, competing with incumbents Netflix and Lovefilm. As Internet companies move into the physical world, research is needed to understand how markets form, emerge, or reach different states of industrial organizational structures.

For several decades, the notion of a market is primarily seen as something out there (being) (Alderson & Cox, 1948) and a natural given, i.e. if there is a good then there is a market (Loasby, 2000). "Once a new product is launched, a new market is created" (Darroch & Miles, 2011, p.723). A market emerges when a firm identifies a latent need in potential demand and communicates a solution to that need (Anderson & Gatigon, 2005, p.401; Diaz Ruiz, 2012, p. 65). Some scholars have started to argue that markets seem to *become* through human effort (Alderson & Cox, 1948; Casson, 1982; Loasby, 2000). From an economics perspective, Loasby (2000) suggests that initial obstacles to trade cause substantial transaction costs between the benefits to the buyer and the direct costs of production of a new product. Markets are the products of investment in continuing transaction capability, accessible to many, and research have suggested that they constitute a form of public good that need to be created, maintained, and managed (Loasby, 2000). In order to overcome obstacles in market creation, Casson (1982) suggests the creation of a system of conventions and rules. For Loasby (2000), these conventions and rules are termed ‘institutions’ (p.298). Markets are therefore not simple aggregation of dyadic exchanges but an institution in their own right, embodying significant investment in physical and symbolic infrastructures (Loasby, 2000). Markets are institutions and institutional arrangements, which could reduce the costs of transactions (Loasby, 2000; Vargo and Lusch, 2016).

Research in Marketing that understand consumer needs and wants could contribute towards the design, configuration, and location of markets (cf. Storbacka & Nenonen, 2011; Ng, 2014). Markets could be created through a complex process of negotiation, expectations, and representations of firms and consumers apart and together, at micro, macro, and mezzo levels through value creation (Peñaloza & Mish, 2011; Peñaloza & Venkatesh, 2006).

3.4.2 Institutions

Like Loasby (2000), marketing researchers such as Ertimur and Coskuner-Balli (2015) have also drawn on the cultural end of organizational studies literature and used institutional theory to discuss the market, addressing its dynamics and evolution. Institutional theory considers institutions as “socially constructed templates for action, generated and maintained through ongoing interactions” (Zucker 1977: p727-728). Institutions could be analyzed at various levels from micro to macro (Barley & Tolbert, 1997). Ertimur and Coskuner-Balli (2015) view markets as an organizational field of “the totality of actors and organizations involved in an arena of social or cultural production and the dynamic relationships among them” (DiMaggio, 1979, p. 1463). In this sense, the market could be defined by the organizations involved in a particular issue or policy community and not by market criteria (Hoffman, 1997; Scott, 2010). By comprehending markets as organizational fields and their corresponding institutional logics, market spaces in IoT could be understood in terms of complementary or competing logics, not by analyzing traditional industry boundaries, but the consumer spaces that they serve. Through the consumer spaces, one could understand how different industries come together. For example, a shower constitutes water, shower gel, light, and wellbeing. Within the activity space, several industries come together to create value for the consumer. Ng (2014) suggests that an organizational field of a ‘value constellation’ in this manner could be a way to understand the institutionalized spaces of consumption and markets and how they map onto business models, i.e. that of the offering (value proposition), the experience (value creation), and the payment model or resource benefit (capture) (Ng, 2013; Amit & Zott, 2001). Such an understanding could help the firm think about its strategy not merely in terms of horizontal or vertical integration, but also tangential innovation to serve its own customers through a different offering in the same consumption space. Thornton, Ocasio, and Lounsbury (2012)’s notion of institutional logics could provide a framework to understand the unfolding social phenomenon of IoT. Institutional logics could help researchers understand an IoT system as a socially constructed layer above the technological layer, with patterns of cultural symbols and material practices, and help interrogate the assumptions, values, and beliefs of the legacy systems.

The principles, practices, and symbols for the institutional order of IoT could become an institutional logic in itself. The institutional logic perspective could provide us with the metatheoretical framework to understand the interrelationships among institutions, individuals, and other entities in the IoT and organizations in social systems; the formation of the inter-institutional system and how different entities perceive and determine value in this system, and the way individuals and organizations create meanings in their daily activities of organizing time and space.

As conceptualized in IoT3, the IoT is a service system and an assemblage of entities that can be continuously assembled and re-assembled. Thus, institutions could also be deemed as an entity in the service system providing the structural properties that are continually assembled and reassembled as well (Vargo & Lusch, 2016).

3.4.3 Economic and Resource Exchange Models

Markets are where the boundaries occur, enabling exchanges to happen. In an era of IoT, with boundaries shifting on where and how value is created for its entities, exchanges are transparently held and easily coordinated, and transaction costs would be lowered in such a way that exchanges of resources other than financial currencies could occur. These could be exchanges of service (Vargo & Lusch, 2008, 2016), or data/information and other resources. These exchanges create new ways of acquiring and re-allocating resources for society as a whole. But exchange is set to change in an era of IoT. Already, a revolution is being initiated by block chains and digital currencies such as Bitcoin. Technically, block chain is described as a distributed ledger, which allows a digital currency to be used in a decentralized payment system [for detailed explanations on how block chain and Bitcoin system works, see Ali, Barrdear, Clews & Southgate, 2014a; b; Böhme, Christin, Edelman & Moore, 2015, p. 215-217; Vora, 2015, p.820). Swan (2015a) argues that block chain should be deemed as “a new organizing paradigm for the discovery, valuation, and transfer of all quanta (discrete units) of anything” (Swan, 2015a, p.vii). This means block chains could potentially be applied to any form of asset registry, inventory, and exchange; any assets (hard such as physical property, objects and intangible assets such as ideas, data, and information) and every area of finance, economics, and money. Due to its decentralized nature, block chains would also enable the exchange of anything with minimal state control or regulation. The implications are profound. Swan considers the block chain technology as one that is potentially used “to expand freedom, liberty, possibility, actualization, expression, ideation, and realization for all entities in the world, both human and machine”(Swan, 2015 b, p.27).

These new economic and resource exchange possibilities that could potentially drive the global economy would require research into models and frameworks that are useful to determine what is workable or not. Moreover, a better understanding of how these connected components that drive markets, institutions, and resource flows could work together in serving society is needed, since changing one set of structures could potentially result in changing all of them, as conceptualized by IoT3 This leads us to form the following research priorities:

- *Emergence and development of new markets and market platforms in IoT*
- *Evolution of structures and institutions logics in an era of IoT*
- *Development of new IoT economic and/or resource models of exchange*

4. Discussion and Conclusion

This paper has proposed four conceptualizations of the Internet-of-Things (IoT), evolved the conceptualizations into a definition of IoT, and elaborated on its implications; that of greater visibility of contexts, the reconfigurability of things, data becoming a service, and shifting boundaries of the industry economy as we know it. We then set out the impact of these implications on Marketing research.

The visibility of contexts would bring the focus of research into understanding consumer experiences, the space where value is created in use and in experience of things we purchase. The ability to instrument and collect real behavioral data would allow researchers to observe and draw insights from individuals' real lives, which could have a real impact on society. We also propose that the move into research on consumer experiences means a shift in the unit of analysis from dispositional to situational traits and the need to conceptualize this new space. Finally, we suggest that behaviors within contexts could potentially be influenced through IoT, by way of nudges and prompts. From this discussion, we propose a set of research priorities for researchers to further knowledge in this space.

The reconfigurability of things focuses on the evolution of the physical product from a static existence into what we term as a dynamic service platform, allowing a set of behaviors in consumption that has infinite degrees of freedom in the permutation of actions. We suggest the move from form and function to that of affordances, i.e. action possibilities, to aid researchers in this theme. We propose that when contextual variety or consumption flexibility is important, the firm designs its offering with a cyber layer to cater for consumer heterogeneity in consumption which would then allow the firm to remain viable through a standardized core. This implication would also lead to new transaction boundaries, and therefore payment and consideration models for future products.

Data as service focuses on personal data in an era of IoT. We propose that personal data holds much promise in markets and society through personalized offerings, but that there is a need for research to address how such data could be transformed and made usable for firms and individuals. We also argue that more research is needed to understand the vulnerabilities associated with personal data at individual, firm, and policy levels.

Shifting boundaries in an economic system is an implication of IoT that would impact on markets, its locations, and how new platforms can emerge. We present the new ways of looking into consumption spaces as the opportunity for market making, proposing that an institutional logic perspective could be useful in understanding the assembling and re-assembling of entities. Finally, boundary shifts could lead to exchanges that are beyond those based on currency, resulting in new economic models for society.

The four implications suggest that an era of IoT will fundamentally transform the firm's business model, to incorporate value creation (the experience – more visible), value proposition (the offering - reconfigurable), and value 'capture' or creating worth for exchanges (ie theeconomic model – with shifting boundaries). Our paper starts the discussion on the challenges involved in that transformation and where innovation could emerge.

We also propose some sample research questions arising from the priority areas in Table 1.

<Insert Table 1 here>

The research priorities posed in this paper suggest some innovative approaches towards research. Some business schools have collaborated with their technology counterparts to instrument shops and live spaces (e.g. JOSEPHS[8]). Others have created 'living labs'[9] to analyse behavioral and social analytics in live environments. Still others have conducted such research within multidisciplinary institutes, centers or business innovation/transformation labs[10]. Indeed, the US National Science Foundation is already issuing calls for research into human-centric smart service systems,[11] specifically calling for an integrated approach towards business and technology[12]. It is clear that research stakeholders in the IoT space are sensing the need to transform traditional approaches into innovative ones.

Our paper suggests a step change for research in Marketing. We posit that human needs haven't really changed. It is only in the way we fulfill them, the time, location, and manner through which they are fulfilled, that is changing. And in an increasingly time-poor society, innovation that gives us more time, makes things efficient, and improves coordination will win. More profoundly however, as technology makes day-to-day living more convenient, individuals may find themselves trading away their choices and freedoms, especially when the product consideration set becomes more limited, or if markets become more monopolistic. Fifty years ago, we had a more diverse set of behaviors in the first half-hour of waking up in the morning; today, 43% of consumers check their smartphones[13]. Since all products are a template for behaviors, societal behaviors evolve to become more rigid and homogenous or more free and diverse, depending on the product consideration set available in markets. In other words, the things we make shape the society we live in. Marketing has a societal responsibility to introduce greater diversity in product choices in

[8] http://www.josephs-service-manufaktur.de/en/
[9] http://centres.smu.edu.sg/larc/
[10] http://www2.warwick.ac.uk/fac/sci/wmg/research/business_transformation/
[11] http://www.nsf.gov/news/news_summ.jsp?cntn_id=136268
[12] http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=504708
[13] Deloitte report (2015) global mobile consumer survey: US edition

a wide range of markets, so that the template of behaviors in IoT products can give greater freedoms and individuals can manifest their authenticity and live more meaningful lives.

An era of IoT has far-reaching implications beyond what has been presented here. This paper makes a start in bringing forward some of the more disruptive elements that have an impact on Marketing and research. Moreover, the full potential of an IoT era has not yet materialised. Where on the Internet, websites are connected and e-mail systems are linked, the IoT world is not (Crowcroft, 2015). The current state of IoT is a collection of fragmented networks of things, using the Internet and other technologies to transfer data to and from each sector's cloud service, rather like the pre-World Wide Web days of the Internet. We argue that the IoT, as it is conceptualized in this paper, is incomplete in its definition and understanding, and is constantly unfolding i.e. an epistemic object, "an object of enquiry, in order to reconfigure it" (Miettinen & Virkkunen, 2005, p.445). What it is largely depends on what its future might be (Rheinberger, 2005). On the basis of such an argument, therefore, we contend that Marketing, instead of regarding the phenomenon as a spectator on the sidelines, has an opportunity to actively participate in this unfolding space, to both reflect and shape the conversations, tensions, and conundrums within its research and practices. Normative models are needed more than before, to steer industrial practices in this space. Research in Marketing led the transformation of markets more than 60 years ago; we should do so again, rather than merely describe them. Our theories and research helped shaped Marketing Management, and trained at least two generations of Marketing professionals that transformed markets and brought innovation to households. As the champions of consumers and individuals, Marketing can do the same in an era of IoT, and in so doing, improve the lives of individuals and society.

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IoT implications	Impact on Marketing Research areas	Research Priorities	Sample research questions
• Visibility of use and experience contexts • The Reconfigurability of Things • Data as a Service • Shifting Boundaries	• Consumer Experience • Dispositions & Situations • Behaviors and Decisions • Product design • Differentiation • Payment Models • Personalization • Vulnerabilities • Markets • Institutions • Economic & resource exchange Models	• Integrating goods and service-based models of consumption and experience • Developing new dispositional-situational models of behaviors • Understanding and influencing behaviors and decisions in context • Designing physical and connected products and platforms for better digital service experiences • Developing new differentiation models with reconfigurable physical and connected products • Creating new payment/consideration models for physical and informational offerings • Innovating on personalised information-based offerings • Understanding and reducing vulnerabilities in IoT • Improving consumer engagement with IoT offerings • Emergence and development of new markets and market platforms in IoT • Evolution of structures and institutions logics in an era of IoT • Development of new IoT economic and/or resource models of exchange	• With visibility of use and experience through IoT data, what models can be created to understand consumption/experience, or the effect of product/service attributes on consumption/experience? • With concepts like practices, routines, norms, how can consumption theories in marketing be empirically testable from IoT data? • What is the effect of reconfigurability on adoption of IoT offerings? • What product attributes can be standardized and what could be personalised in IoT offerings? • How do we model the trade-offs of consumer, firm, and state interests in privacy, trust and security? • What types of mitigation measures would affect perceived vulnerability of individuals? • What types of choice-based, usage-based or attribute-based pricing models could be created and how would it have an impact on adoption/purchase/usage of IoT products?